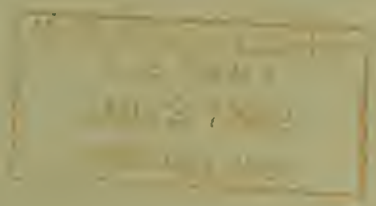
Transplanting Adult Pink Salmon to Sashin Creek, Baranof Island, Alaska, and Survival of Their Progeny



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ABSTRACT

The return of adult pink salmon, Oncorhynchus gorbuscha, to Sashin Creek was very low in the even years from 1946 to 1962. In 1964 an experiment tested a method of transplanting adults to reestablish the even-year run of pink salmon.

About 2,400 adult pink salmon were captured in a purse seine in Bear Harbor and transported alive in brine tanks on a boat to Sashin Creek, a distance of about 80 km. (50 miles). Most of the fish survived the trip; 727 males and 1,139 females were put into Sashin Creek above a weir. The transplanted fish were augmented by 166 females and 121 males of unknown origin that entered the stream naturally.

The distribution of the spawners in the stream was similar to that of native runs of the same size. Survival of the eggs and progeny from a potential deposition of 2,230,000 eggs was relatively good for Sashin Creek--55 percent to the end of spawning and 14 percent to fry emergence the next spring. The survival of these fish in the ocean was also relatively good, and about 6,000 adults (2 percent of the fry) returned to spawn in 1966. These fish spawned successfully, and survival of fry in 1967 from the potential egg deposition was 12 percent.

INTRODUCTION

Recognition of home waters is a well-accepted trait of salmon; and if they are transferred from their native water to another area as eggs or young fish, most of the surviving adults will return to the new stream or lake even though no ancestral ties exist. This behavior makes it possible to transplant a self-perpetuating population of salmon from one stream to another.

Salmon can be transplanted in several ways. Perhaps the most common is to obtain eggs from a donor stock, hatch them in a hatchery, and release the juveniles in a recipient stream. This procedure may be modified somewhat to approximate natural conditions more closely by burying eyed eggs from a hatchery in an egg incubation channel which is a part of the recipient stream. A third method is the transplantation of unspawned adult salmon from one stream to another. By this method the adults are allowed to spawn naturally, and the young are exposed only to natural conditions.

Most accounts of transplants of adult salmon in large numbers have involved chinook, Oncorhynchus tshawytscha; coho, O. kisutch; and sockeye salmon, O. nerka. Although the transplanted fish usually spawned in the recipient stream, they sometimes died unspawned or left the recipient stream without spawning (Needham, Hanson, and Parker, 1943; Fish and Hanavan, 1948; Andrew and Geen, 1960; Sams[4]).

Past attempts to introduce pink salmon, O. gorbuscha, to barren waters or to supplement their numbers have usually involved transplanting eyed eggs or fry. These introductions have generally failed to establish permanent increases in the number of adults, although occasionally they produced an abundance of fry and returning spawners in the first cycle (Wickett, 1958; MacKinnon, 1960, 1963;

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[4] Sams, Roy. Transplantation of adult coho salmon. Proc. NW. Fish Cult. Conf., December 1967. (Unpublished.) Author's present address, Fish Commission of Oregon, Clackamas, Oreg. 97365.

Pritchard, 1938). Several attempts were made in Washington State to reestablish a run of pink salmon by transplanting fry, but the only self-perpetuating population of pink salmon resulted from the release of "short-term reared" fry at a hatchery (Noble, 1963). A few attempts to transplant small numbers of adult pink salmon have yielded inconclusive results.

Pink salmon live 2 years from fertilization of ova to maturation as adults. The adults die soon after spawning, and even- and odd-numbered brood years or lines[5] are genetically separate. They are often abundant or scarce in alternate years in individual streams throughout their range. This disparity in numbers between even- and odd-year lines may persist for a decade or longer (Ricker, 1962).

A marked disparity in numbers in even- and odd-year lines of pink salmon has existed for many years in Sashin Creek on Baranof Island, southeastern Alaska (Olson and McNeil, 1967). Spawners were abundant in even- and odd-numbered years between 1934 and 1945, after which both lines declined sharply until 1957 when spawners again became abundant in the odd years. Those in the even years remained scarce through 1958. In 1950, 1952, 1960, and 1962 most of the adults and fry were killed in an attempt to determine the numbers of adults that strayed into Sashin Creek.[6] The relatively few adults in the even-year lines between 1952 and 1964 were probably mostly strays from other streams.

In 1964 we transplanted adult pink salmon from another area to Sashin Creek to develop handling methods and to reestablish a significant even-year line. In this report we describe the methods used to transplant the adults and discuss their distribution on the spawning ground and the survival of their progeny in fresh water and the ocean.

TRANSPLANTATION TO SASHIN CREEK

The adult pink salmon transplanted to Sashin Creek in 1964 were taken from the estuary of a small stream in the North Arm of Bear Harbor (fig. 1). Most of the adult pink salmon normally enter and spawn in the Bear Harbor stream between mid-August and mid-September (Rosier, Johnston, and Orrell, 1965)--the same time that adults enter Sashin Creek. We made no observations on the physical characteristics of the Bear Harbor stream.

Several thousand adult pink salmon were captured with a purse seine in Bear Harbor at 0900 hours on August 23, 1964. Part of the catch was brailed into two tanks of sea water aboard the MV Jack B.[7] Each tank measured 1.8 by 1.8 by 6.3 m. and received 870 liters of fresh sea water per minute. Water was pumped in through the bottom and overflowed at the top.

Loading was completed at 1030, and the Jack B. arrived at Little Port Walter Bay (the estuary of Sashin Creek) at 1745. The fish were released into a floating pound (10 by 10 by 2 m. deep) at 1800.

The first fish was removed from the pound and released above a weir in Sashin Creek on August 25 (2 days after capture), and the last was released on August 28. The fish were transported the 400 m. from the pound to the stream in small floating pens (1.7 by 3.3 by 1.0 m. deep). Herring purse seine netting (square mesh openings of 2.5 cm.) was used in the pound and pens. A more detailed description of the capture and transport of the fish from Bear Harbor to Sashin Creek appeared in a preliminary report.[8]

Of 2,395 pink salmon put into the tanks of the Jack B., 388 died en route to Little Port Walter Bay and five died later (17 percent of the females and 10 percent of the males). Some salmon were dead on the bottom of the tanks after the fourth hour in transit, but the cause of their deaths is not known. Although the water that overflowed from the tanks contained only 3 mg./l. of dissolved oxygen, no distressed fish were seen at the surface of the tanks. Factors that could have contributed to the deaths were buildup of blood lactate levels from hyperactivity (Black, 1958; Parker, Black, and Larkin, 1959) and psychological stress (Ellis, 1964), and internal injuries from handling.

We released 727 males and 1,139 females in Sashin Creek above the weir and 150 tagged males into the bay. Thirty-six untagged fish escaped into the bay (table 1).

Between August 30 and September 19, 327 adult pink salmon (161 males and 166 females) swam through the weir and entered Sashin Creek. Forty of these were from the group of 150 males tagged and released in the bay. Presumably the rest (121 males and 166 females) originated in other streams and strayed into Sashin Creek. This presumption is based on our belief that we killed all of the fry produced by the four female pink salmon that spawned in Sashin Creek in 1962.

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[5] The term "brood year" refers to the year of spawning and is not necessarily synonymous with "year class." The term "line" was used by Ricker (1962) because there is no genetic interchange between odd and even years.

[6] Harry, George Y., Jr., and Jerrold M. Olson. 1963. Straying of pink salmon to Sashin Creek, Little Port Walter Bay. Manuscript on file Bur. Commer. Fish. Biol. Lab., Auke Bay, Alaska.

[7] Vessels and crews for this experiment were loaned by Pacific American Fisheries, Inc.

[8] Smedley, Stephen C., and William J. McNeil. 1966. Freshwater survival of pink salmon transplanted to Sashin Creek, Baranof Island, Alaska. State of Alaska, Department of Fish and Game, Informational Leaflet 91, 21 pp.

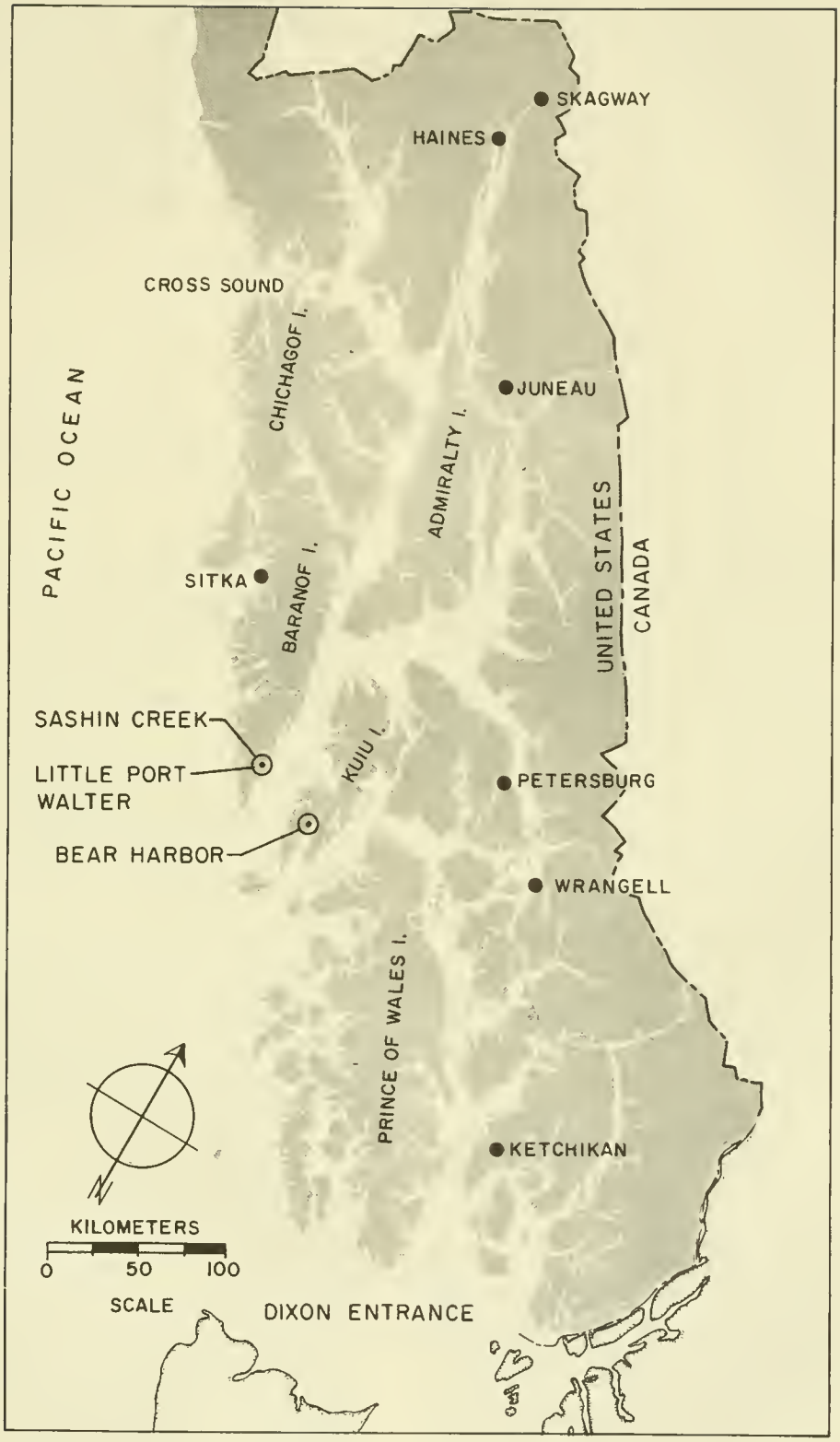

Figure 1.--Sashin Creek, Bear Harbor, and Little Port Walter, southeastern Alaska.

Table 1.--Disposition of 2,395 adult pink salmon (1,008 males, 1,387 females) transported from Bear Harbor to Little Port Walter in 1964

Date	Fish released in Sashin Creek		Fish tagged and released in the bay		Fish escaped untagged in bay		Fish dying before release	
	Male	Female	Male	Female	Male	Female	Male	Female
	Number	Number	Number	Number	Number	Number	Number	Number
Aug. 23	--	--	--	--	--	--	101	237
24	--	--	--	--	--	--	--	--
25	48	90	0	0	3	1	0	0
26	154	254	0	0	20	5	0	1
27	340	488	0	0	5	2	0	1
28	185	307	150	0	0	0	2	1
Total	727	1,139	[1] 150	0	28	8	103	240

[1] Forty of the tagged males entered Sashin Creek of their own volition.

Table 2.--Pink salmon in pools at various distances upstream from the weir, Sashin Creek, 1964. Fish were released into Sashin Creek August 25-28

Date	Pink salmon in pools upstream from weir					
	0 m.	366 m.	610 m.	732 m.	793 m.	915 m.
	Number	Number	Number	Number	Number	Number
Aug. 25	138	0	0	0	0	0
26	541	5	0	0	0	0
27	1,354	20	0	0	0	0
28	1,769	60	25	10	2	0
29	1,676	150	25	10	2	3

Table 3.--Estimates of the density of female pink salmon spawners in four sections of Sashin Creek, 1964

Section	Total females	Surface area	Females per square meter
	Number	M.^{2}	Number
I (upstream)	39	2,945	0.01
II	382	4,067	0.09
III	441	3,747	0.12
IV (downstream)	391	2,325	0.17

DISTRIBUTION OF SPAWNERS

Sashin Creek has 13,629 m.^{2} of spawning ground between the weir and an impassable falls. The distance between the weir and the falls is 1,200 m., but the upper 300 m. are mostly in a narrow canyon and are rarely used by indigenous pink salmon for spawning.

The transplanted fish began to move upstream from the weir within 24 hours after they were released above the weir. Five pink salmon were in the pool 366 m. above the weir on August 26, 1 day after the first fish were released into the stream (table 2).

We divided the spawning ground[9] into four sections and counted the number of female pink salmon in each section daily. Section I was farthest upstream and section IV farthest downstream. Together the sections included 96 percent of the total spawning ground: section I--22 percent, section II--30 percent, section III--27 percent, and section IV--17 percent.

[9] The spawning ground is that portion of a stream usable for spawning and does not include pools.

A total of 2,193 pink salmon spawners entered Sashin Creek in 1964, of which 1,305 were females. The first female occupied the spawning ground August 28, and the die-off of spawned female pink salmon was complete by October 3. Spawning reached its peak on September 16, when 695 females were counted on the spawning ground.

We assumed that 1,253 females, or 96 percent of the 1,305 females in the stream, spawned in the four study sections. The percentage spawning in each section was obtained by summing the daily counts in each section and dividing this number by the summed daily counts in all sections.

The density of female pink salmon was highest in downstream section IV and lowest in upstream section I (table 3). This distribution is characteristic of small runs of pink salmon in Sashin Creek (Merrell, 1962). Although fresh-water survival of pink salmon is better in section I (McNeil, 1966; 1968), this area is only lightly used except in years of large runs.

Table 4.--Comparison of estimates of survival of pink salmon fry in Sashin Creek before the fry emerge (hydraulic sampler) and at the time they migrate (weir), 1959-63 (from McNeil, 1968)

Brood year	Estimates of survival	
	Hydraulic sampler	Weir
	Percent	Percent
1959	11.0	13.2
1960	([1])	([1])
1961	21.4	20.2
1962	0.0	1.2
1963	20.7	19.6
Mean	13.3	13.6

[1] Survival was not estimated in 1960.

SURVIVAL OF EGGS AND ALEVINS

Total fresh-water survival of the eggs and the developing young of pink salmon in Sashin Creek has been estimated since 1940 (Olson and McNeil, 1967). These estimates of survival are calculated from the number of eggs carried into the stream by the adult females (potential egg deposition) and the number of fry migrating to the estuary. A weir had been used to collect the fry that we counted; but because it was severely damaged by ice in winter 1965, we estimated the number of alevins in spawning beds just before the fry emerged. In previous years, estimates of the number of survivors in late March or early April shortly before fry emerged from the gravel were similar to estimates made at the weir in late May or early June when fry migrated to the estuary (McNeil, 1968--see table 4).

Potential egg deposition in 1964 was calculated to be 2,230,000. This figure was obtained by multiplying the number of females in Sashin Creek (1,305) by the average fecundity of 25 females that died en route from Bear Harbor (1,709 eggs).

The number of live pink salmon eggs and alevins in spawning beds is determined by sampling randomly selected points with a hydraulic sampler (McNeil, 1964). Total population of the 1964 brood year in early April 1965, calculated from sample counts, was 310,000 live alevins. The 90-percent confidence interval estimate of the total, calculated from log-transformed counts (McNeil, 1964), was

$$180{,}000 < \mu < 390{,}000$$

Survival of the 1964 brood year in fresh water was determined for two time periods by estimating the number of live eggs or embryos at three stages in the pink salmon's life history: (1) before spawning (potential egg deposition); (2) at the end of spawning (actual number of live eggs in the gravel); and (3) at the beginning of fry emergence (number of fry produced). Figure 2 illustrates the fresh-water survival from potential egg deposition to fry for pink salmon of the 1964 brood year in Sashin Creek.

We sampled 261 random points in Sashin Creek in late September. These samples yielded 2,360 eggs; the lowest density was in section I and the highest in section IV (table 5), as was anticipated from the distribution of spawners (table 3). Ninety-eight percent of the eggs collected contained visible embryos, which indicated that the relatively low percentage of males in the population of spawners (42 percent) did not cause a high percentage of unfertilized eggs. Usually the numbers of male and female pink salmon spawners in Sashin Creek are nearly equal.

The number of live embryos in the stream at the end of spawning was estimated from the sample counts (untransformed) to be 55 percent of potential egg deposition. Examination of 40 spawned females gave the 90-percent confidence interval estimate of the number of eggs retained per female as $5 < \mu < 17$, or on the average less than 1 percent of potential egg deposition. Thus, an estimated 44 percent of potential egg deposition disappeared during spawning.

An estimated 25 percent of the live embryos in the spawning beds in late September survived to early April. The lowest density at the beginning of fry emergence was in section I and the highest in section IV (table 5). Hence, the relatively high density of live embryos and alevins in the downstream section did not change appreciably from spawning to just before fry emergence.

The total fresh-water survival (through early April) was estimated to be

$$\frac{310{,}000 \text{ (live alevins)}}{2{,}230{,}000 \text{ (potential egg deposition)}} \times 100 =$$

13.9 percent.

The 90-percent confidence interval was 8.1 percent $< \mu <$ 17.5 percent.

The 13.9-percent fresh-water survival of the 1964 brood was more than twice the 6.3 percent average of 22 previous broods (table 6). Before 1964, fresh-water survival of the even-year line was less than average. In contrast, the fresh-water survival of the odd-year line has been greater than average since 1951.

Fry have been scarce from the even-year line for almost 2 decades (table 6), in part because of attempts to annihilate this line. The relatively high fresh-water survival of spawn from the adults introduced in 1964 produced the largest number of fry from the even-year line since 1942.

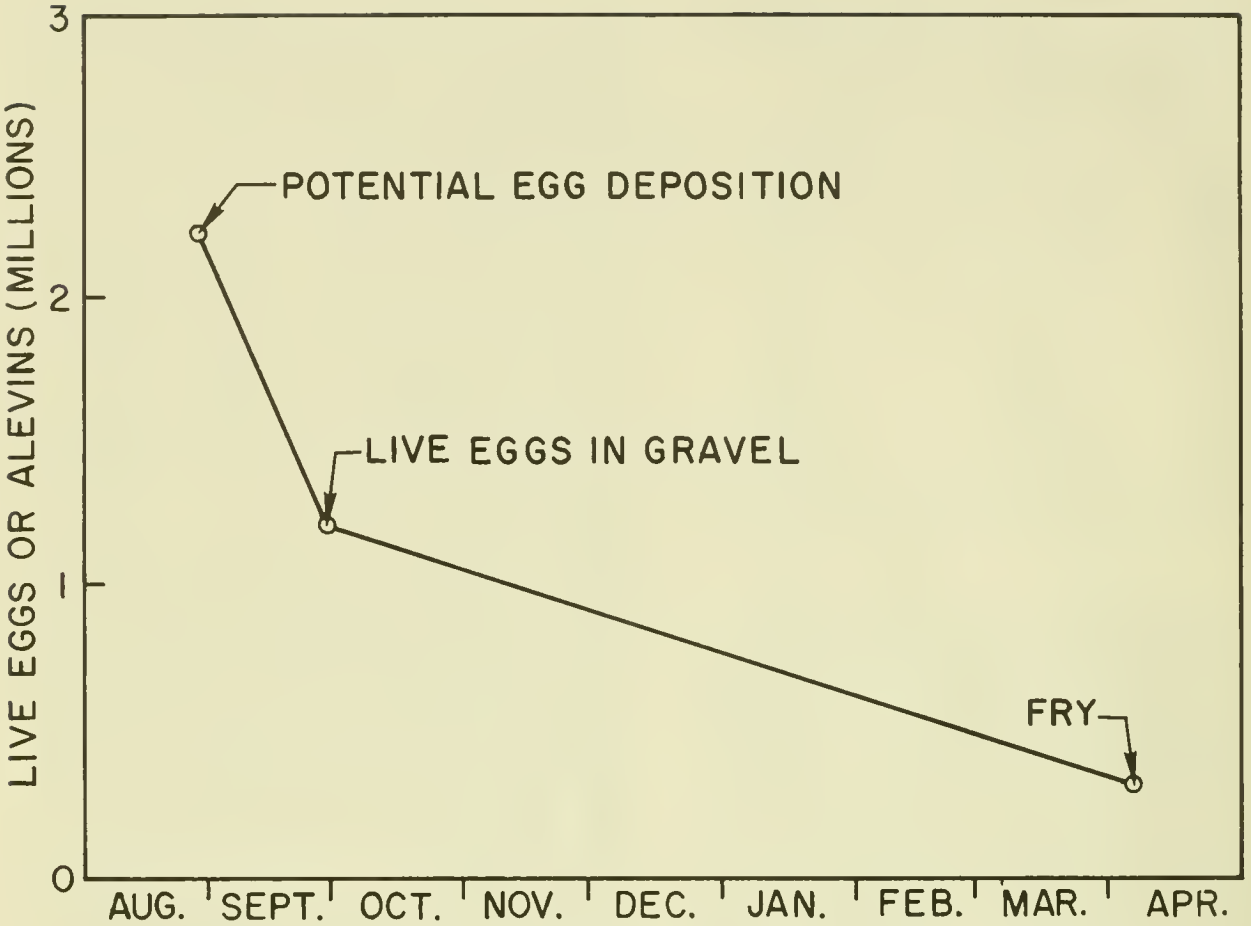

Figure 2.--Fresh-water survival from potential egg deposition to fry for the 1964 brood year adult pink salmon in Sashin Creek.

Table 5.--Density of 1964 brood year pink salmon in study sections from spawning to fry emergence, Sashin Creek

Section	Estimated potential egg deposition per square meter	Estimated surviving embryos per square meter at end of spawning	Estimated surviving alevins per square meter at beginning of fry emergence
	Number	Number	Number
I	23	[1] 0	[1] 1
II	161	91	23
III	201	100	17
IV	287	194	59
stream	164	91	23

[1] The increase from 0 to 1 is consistent with anticipated errors in sampling.

RETURN OF SPAWNERS

About 6,000 adult pink salmon returned to Sashin Creek to spawn in the summer of 1966 (Ellis, in press) from about 1,900 transplanted and 300 stray adults in the summer of 1964. This number was about 2 percent of the 310,000 fry that migrated to sea in spring 1965. The estimates of ocean survival based on the number of adults returning to the weir are useful, although they are minimum estimates because the intensity of the commercial fishery on Sashin Creek pink salmon is unknown. Before 1966 the number of spawners returning to Sashin Creek averaged 3 percent (range 0.3 to 18 percent) of the number of fry migrating to sea (calculated from data presented by McNeil (1968) for 18 observations from 1940 to 1965).

The migration of adults to Sashin Creek in 1966 was earlier than usual. The first adults entered the creek on August 23, 1966, and 50 percent of the total number had entered by August 31. In the past, pink salmon have entered Sashin Creek from early August to late September. Twenty-eight years of observation show that 50 percent of the total number of spawners may be in the creek as early as August 13 or as late as September 18 (McNeil, 1968). The average date has been September 11 for even-year lines and September 2 for odd-year lines.

Table 6.--Survival of even- and odd-numbered brood year pink salmon in Sashin Creek, 1940-63 (Data from Olson and McNeil, 1967)

Brood year	Even year			Brood year	Odd year		
	Potential egg deposition	Fry produced	Survival		Potential egg deposition	Fry produced	Survival
	Number	Number	Percent		Number	Number	Percent
1940	52,858,000	3,400,000	6.4	1941	88,678,000	1,024,000	1.2
1942	78,894,000	674,000	0.8	1943	14,980,000	228,000	1.5
1944	3,904,000	106,000	2.7	1945	5,062,000	43,000	0.8
1946	736,000	1,200	0.2	1947	1,330,000	27,600	2.1
1948	516,000	9,100	1.8	1949	4,800,000	176,000	3.7
1950	86,000	50	0.1	1951	4,062,000	412,000	10.1
1952	([1])	--	--	1953	1,284,000	95,400	7.4
1954	12,000	660	5.5	1955	10,286,000	1,266,000	12.3
1956	1,018,000	5,050	0.5	1957	2,588,000	563,000	21.8
1958	174,000	10,700	6.1	1959	40,379,000	5,332,000	13.2
1960	([1])	--	--	1961	29,425,000	5,940,000	20.2
1962	8,000	100	1.2	1963	16,640,000	3,256,000	19.6
Mean survival --		--	2.5	--	--	--	9.5

Grand average = 6.3 percent
[1]No escapement.

Early entry of pink salmon into Sashin Creek is accompanied by early spawning because most of the fish have matured before they enter the creek. Early stream entry in the past has been followed by higher survival of eggs and alevins than late stream entry (McNeil, 1968). Merrell (1962) thought that eggs deposited early get a "head start" before cold weather retards development during the sensitive period immediately after fertilization. The observations of Azbelev, Surkov, and Yakovenko (1962) support this contention.

Survival from the 1966 spawning was also high (about 12 percent of potential egg deposition). About 750,000 fry migrated to sea in the spring of 1967 (Ellis, in press). Thus, the long-standing scarcity of pink salmon of the even-year line in Sashin Creek now appears to have been reversed. Figure 3 shows the decline of spawners from both odd- and even-year lines in the 1940's, the recovery of the odd-year line in the late 1950's, and the very recent recovery of the even-year line through transplantation. We recognize that attempts to annihilate the even-year line in 1950, 1952, 1960, and 1962 may have prevented the natural recovery of the even-year line.

RECOMMENDATIONS

Vessels equipped with large tanks for refrigerated sea water (brine boats) are now commonly used in Alaska to transport commercial salmon catches to canneries. Successful introduction of adult pink salmon to Sashin Creek in 1964 demonstrates that it is feasible to use these vessels to transfer seine-caught pink salmon to streams where fish are scarce.

The experiment described in this paper was done to develop and test techniques, and we caution against indiscriminate transplantations of fish, because of the possibility of undesirable effects from the mixing of genetically dissimilar stocks. If a recipient stream is nearly devoid of spawners (as was Sashin Creek), we foresee little danger from such interbreeding. If the recipient stream possesses a significant native population of spawners, one gambles with the possibility of introducing unfavorable genetic characteristics. Under these circumstances, we would favor an attempt to rebuild the native population by protecting it from the fishery rather than by introducing spawners from another stream. Should knowledge of genetic characteristics of populations become adequate, it might someday become feasible to substitute genetically superior populations of pink salmon for native populations.

To increase the chances of success in rebuilding pink salmon runs by transplantation of adults, the native and introduced fish should be similar in terms of timing of migration and spawning. It might also be desirable for temperature and other characteristics of spawning beds of the donor and recipient streams to be similar, because failure to establish a run might result from genetically determined inability of an introduced stock to adapt to a new environment.

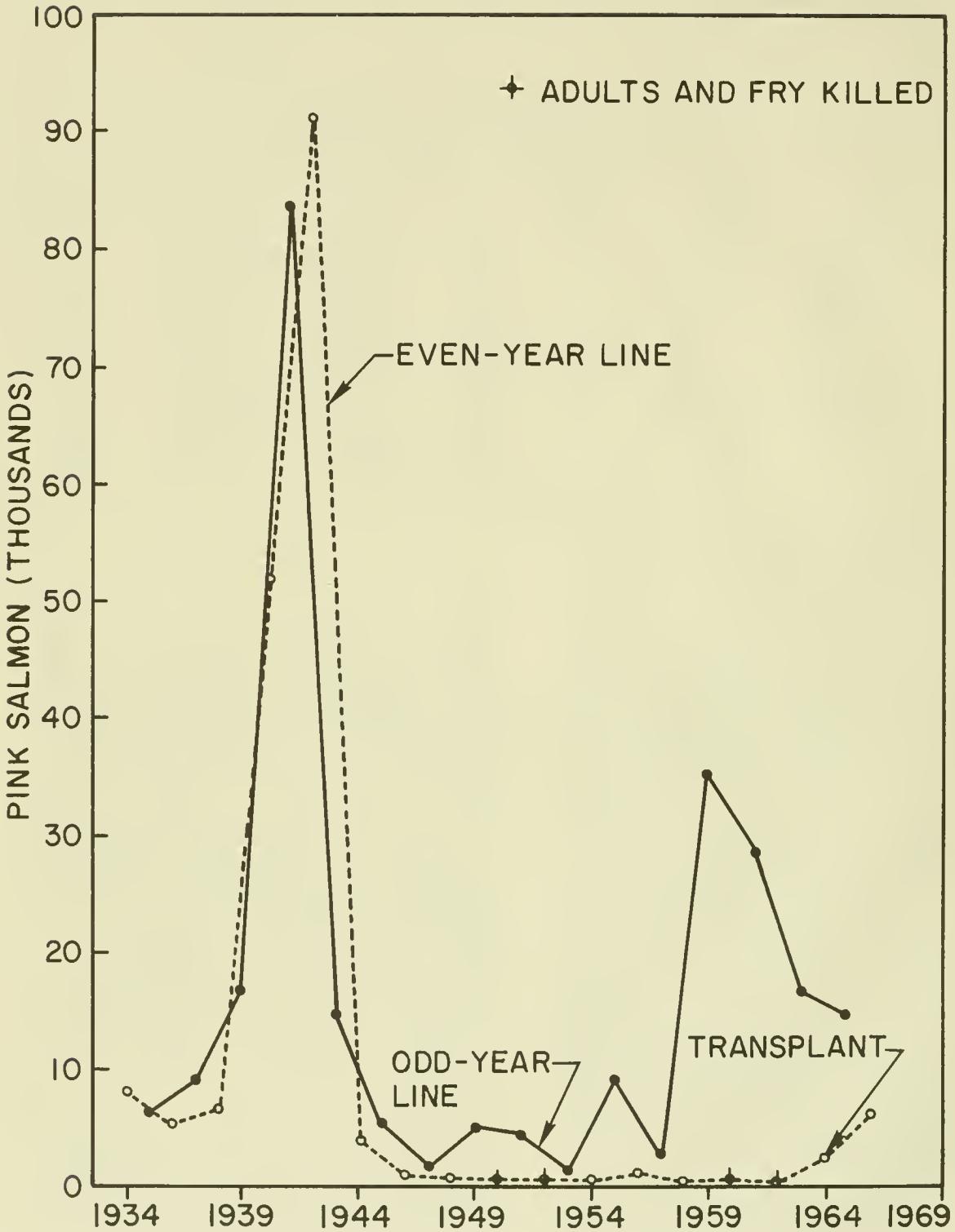

Figure 3.--Number of pink salmon spawners, Sashin Creek, 1934-66.

ACKNOWLEDGMENTS

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DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE
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